Appendix I - Port of Guaymas Simulation

1. Introduction

The preliminary estimation of the capacity of the Port of Guaymas in terms of TEU is performed through the present simulation model. The model is based on the ProModel® V6.0 Montecarlo simulation package and its aim is to obtain a valid, logical representation of the performance of the port if container service is established. Some of the elements built into the model include: current and predicted levels of infrastructure, scheduled arrivals of container ships, internal operations of container terminal and rail and truck entry and exit processes. The characteristics built into the model are in accordance with the Master Development Plan (2005) developed by the Port of Guaymas. However there is not an operating container terminal currently on the port. So we designed the potential operation of the terminal based on our review of similar ports the UNCTAD Port Development Handbook (1985) and on interviews with operations personnel from the Port of Guaymas.

The main objective of the simulation is to estimate the current capacity, resource needs (cranes, trackers, forklifts) and bottlenecks. This technique allows generation of several scenarios with different port configurations (resource availability and capacity, arrival and service time policies) in order to evaluate different potential outcomes.

2. Process Flow

The first requirement of the simulation model is to design flow of the different entities in the system, since every simulation is built around the resources used by the entities in the system. The entities we designed for the present model are the container vessels, the import containers and the export containers. The flow of the vessels is presented in Figure 1, which presents the main activities performed from the time the vessel arrives to the Port until its departure. For the purpose of the simulation we are interested in the time required by each one of these operations, and the overall time the vessel spends in the Port, which is commonly known as turnaround time. The vessels have two main attributes the type of cargo (container or general cargo) and the amount of import containers that downloads in the port.

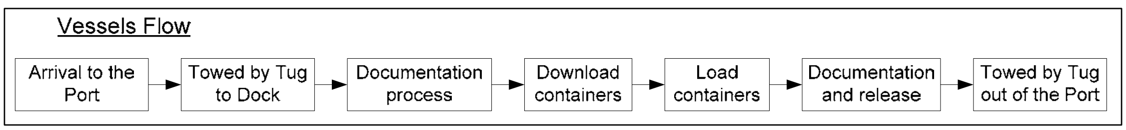

Figure 1 - Flow of Container Vessels

The second entities in the system are the containers destined for import (the ones downloaded by the vessel). These containers are generated in the system when the vessels start downloading them according to the attribute for container cargo. Figure 2 describes the flow of activities required from the time the containers are downloaded from the vessel up to the point where they are dispatched according to the preferred transportation mode. The physical flow of the import containers is presented in Figure 3, where it is shown the main routes out of the port for both railroad and truck. For the purpose of our simulation we only use two transportation modes: trains and trucks. The main attributes for container imports are the size of the container (40 or 20 feet) and the preferred transportation mode. With this attributes we can change the mix of different containers and the mix of transportation modes according to the selected scenarios for the simulation, which we will cover in a later section.

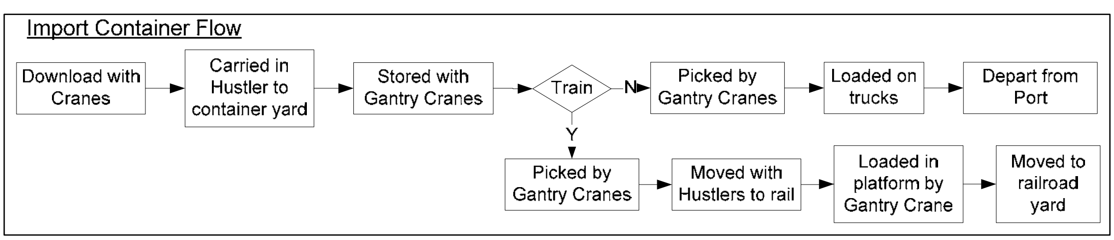

Figure 2 - Flow of Import Containers

Figure 3 - Flow of Import Containers

The third entity are the export containers, that should arrive at the port before the vessel and are loaded into the vessel once all the import containers have been downloaded. We assumed that all the export containers would arrive by truck and should be stored in a particular area of the port, separated from the import containers following the process of Figure 4. The activities performed by these containers are the arrival at the gate of the port, the storage in a particular area and then loading them to the vessel. The physical flow of these containers is presented in Figure 5, where it can be observed that the containers only enter through the main gate for trucks and then stored at the container terminal.

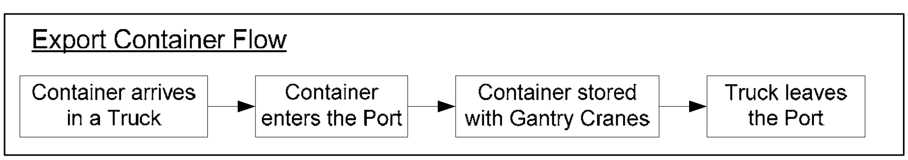

Figure 4 - Flow of Export Containers

Figure 5 - Flow of Export Containers into the Port

3. Assumptions of the System

As explained before, the Port of Guaymas does not currently have a container terminal and has not received any container cargo for some years. So most of the design and the operation of the container model is carried out by assumptions regarding the future and present characteristics of the Port of Guaymas. Through this section we describe the major assumptions that considered in the design of the simulation model.

3.1. Locations

The locations of the physical equipment was developed according to the engineering plans and in consultation with operations personnel regarding the feasible and best location of the equipment in the Port. The physical infrastructure includes the position of berths, container yards, gates, railroad and the flow of trucks within the Port. Currently there are two dock positions available for containerized cargo vessels, and two more for other types of cargo, as it is shown in Figure 6. Each berth can only process one vessel at a time; we assumed no more than two cranes per berth to process each shipment, which can be changed once the activity in the port requires the investment in more equipment.

The container yards are located near the two container berths as it is shown in Figure 6. One of the assumptions we made is that the layout of the container yard would be similar to the container yards that use gantry cranes, with blocks of 6 containers across and aisles with capacity for two trucks and the legs of the gantry cranes. The gantry cranes in Guaymas can only stack 3 containers high, so the total capacity of the yards, as it appears in Table 1 is of 6,552 containers at the same time.

Infrastructure	
Number of Yards	2
Aisles per Yard	7
Positions per Aisle	39
Capacity per Position	4 width x 3 height containers
Capacity per Yard	3,276 containers
Total Capacity	6,552 containers

Table 1 - Infrastructure of Containers Yards

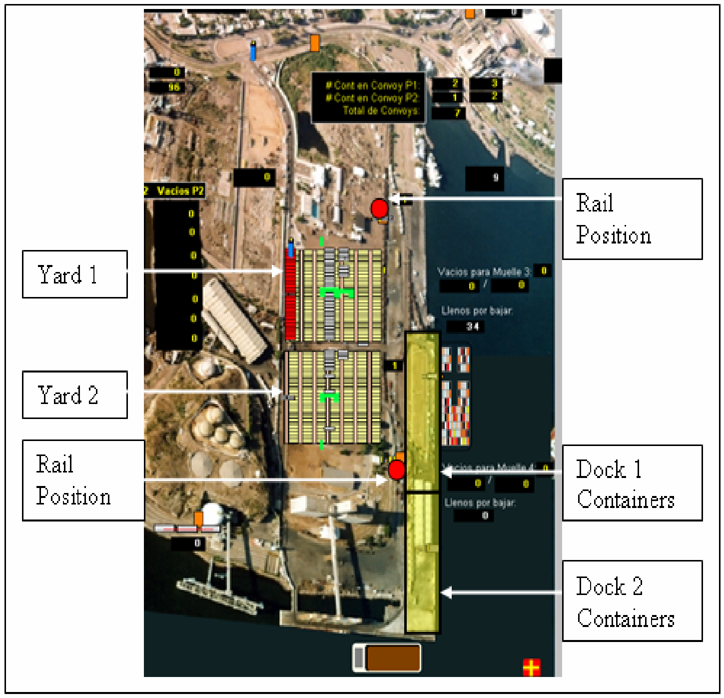

Figure 6- Representation of the Container Terminal at the Port of Guaymas

In the container yard, the three closest aisles to the docks in each yard were assumed to be dedicated only for refrigerated containers. There is a railroad position per yard to load containers with capacity of 4 platforms and sidings to prevent blocking the flow in the port (see Figure 6). There is also a railroad position next to the container yards where up to 15 loaded platforms can be stored before being moved out of the port to the railroad yards in Empalme.

3.2. Resources

The resources used can be divided in infrastructure in equipment. For the most part the infrastructure required to operate the container terminal is in place, with the only caveat of increasing the draft of the berths, which we assume will happen some time soon. The second aspect is the equipment to use in the operation of the port terminal, which is presented in detail on Table 2. Some of this equipment is already available, like the yard cranes, and forklifts, and tugs, but some other is not, such as the hustlers quay cranes and the railroad modules required to send containers by train.

Equipment	Quantity
Hustler	12
Hustler (to train)	8
Yard Crane	3
Quay Crane	0
Ship Crane	2
Forklift	12
Module	15
Tug	2

Table 2 - Equipment Used in the Simulation

We assumed the existence of such equipment because is necessary for the operation of the container terminal, an in case the terminal start its normal operation, it will require to buy such equipment. The equipment with the highest cost (also the most restrictive) is the quay cranes, which is the reason for simulating their effect on the scenarios we developed.

The travel speed for each type of equipment to go from one place to another was assumed estimated according to the performance provided by equipment currently at the port. The times assume a uniform distribution with the means provided in Table 3.

Equipment	Speed
Train	9 km/h
Truck	40 km/h
Forklift	3 km/h
Yard Crane	10 km/h
Hustler	20 km/h
Tug	5 km/h

Table 3 - Characteristics of the Equipment

3.3. Arrivals

The arrival of non-containerized cargo vessels to the port was assumed to be deterministic, and the time between arrivals was set to 168 (one vessel per week) and 56 hours (three vessels per week). For the scenarios with 400 and 1,200 TEU respectively, we also simulate arrivals of other vessels, such as general cargo and oil tanks, which are generated with a random arrival based on a five year history of arrivals to the port.

Other arrivals included the export containers, which were estimated with random arrival over the previous days before the departure of the vessel. We assumed that these containers arrive only by truck, so all of the entries occur at the gate of the port. Export containers arrivals are assumed exponentially distributed with a mean to match the export requirements for the simulation. It is assumed that export containers will not be loaded in the vessel until all full containers have been unloaded.

3.4. Processing Time

We call it processing time at the time each resource spends busy with an entity in our model. To get this information for the port of Guaymas we researched in other ports the time it took them to operate their equipment and from the information provided by the Port of Guaymas operations for the equipment currently at the port. The following times are the ones we use for the simulation:

Vessels

Transit time between the arrivals of the vessels and the buoy was assumed deterministic and set to 10 minutes. Then the transit time between the buoy and the dock position (tug pulling vessel) was assumed deterministic, these times are presented by Table 4. Processing times for non-containerized cargo in docks 5 and 6 were assumed to be deterministic and set to 75 hours from the time they arrive to the time they are released.

Time Required	
Dock Position 3	52 minutes
Dock Position 4	45 minutes
Dock Position 5	45 minutes
Dock Position 6	52 minutes

Table 4 - Time Required to Arrive at the Dock

Cranes

After a containerized cargo vessel arrives to a dock position, there must be time destined for authorities of the port to release the vessel for unloading as well as for the crew to get ready to unload containers. This time was assumed to be deterministic and set to 1 hour.

The time required for each type of equipment to do one loading or unloading cycle is presented in Table 5. These times have a mean and a standard deviation associated with them, with the objective of representing the regular operation of container terminals

Equipment	Distribution	Mean	Standard Deviation
Ship Crane	Normal	400 sec	100 sec
Quay Crane	Uniform	150 sec	15 sec
Forklift	Uniform	30 sec	1.5 sec
Yard Crane	Uniform	60 sec	3 sec

Table 5 - Processing Times for Different Cranes at the Dock and Yard

Container Processing

Once a container enters the yard, some time must be destined for the port authorities and customs to release it, as well as for the necessary equipment for movement (truck or train) to be available. A uniformly distributed waiting time with mean of 3 hours and standard deviation of 1hr was assumed for the time required for a container to be ready for pickup.

Train Platforms

It was assumed that platforms to load containers that will be moved by train store two containers each and come in modules of four. That means every time containers are being loaded into platforms there are four of those available to be filled before moving that module to the waiting location. Once the 15 modules are ready to be sent in the waiting location, they are moved out of the port to Empalme where Ferromex get's them ready to go. Since its being assumed that there are only 15 modules available at any time, once those are sent to Empalme 4 hours must pass in order to have platforms available in the port.

3.5. Simulation Scenarios

According to the objectives of our simulation, we developed different scenarios aimed at finding the main bottlenecks in the Port and also estimating the service provided by the container terminal. The first factor considered on the scenarios is the equipment, which is presented on Table 6, where the first modification (Equipment 1), uses the current infrastructure in the port, with some minor additions. The main characteristic of this level of infrastructure is the loading and unloading of containers with the cranes from the container vessels. The second design in Table 6 assumes the purchase of two quay cranes that can be used to unload containers from the vessels, without the need of the ships' own cranes. The more realistic is the first type of equipment, since it is almost the current equipment available at the port, with only minor adjustments. However from the results we obtained, the low equipment might not be the most adequate service for the type of container cargo the port should focus on, as we will see later in this report. Both of these levels of equipment are presented in Table 7 on columns 7-14 as part of the overall scenarios designed for the simulation.

Description	Current	Equipment 1	Equipment 2
Container Quay Cranes	--	--	2
Container Yard Crane	2	3	3
Forklifts	22	12	12
Chassis	7	12	12
Trucks	3	7	7
Container Shuttle (Hustlers)	5	12	12
Yard Capacity in Containers	--	6552	6552

Table 6 – Infrastructure between the Current State and the Simulated Scenarios

		Containers/Week		Ship Method									
Cases	TEU	Full	Export	Truck %	Train %	Hustler	Hustler FC	Yard Crane	Quay Crane	Ship Crane	Forklift	Module	Tug
1	400	230	168	0	100	12	8	3	0	2	12	15	2
2	400	230	168	100	0	12	8	3	0	2	12	15	2
3	400	230	168	50	50	12	8	3	0	2	12	15	2
4	400	230	168	30	70	12	8	3	0	2	12	15	2
5	400	230	168	70	30	12	8	3	0	2	12	15	2
6	1200	690	480	0	100	12	8	3	0	2	12	15	2
7	1200	690	480	100	0	12	8	3	0	2	12	15	2
8	1200	690	480	50	50	12	8	3	0	2	12	15	2
9	1200	690	480	30	70	12	8	3	0	2	12	15	2
10	1200	690	480	70	30	12	8	3	0	2	12	15	2
11	400	230	168	0	100	12	8	3	2	0	12	15	2
12	400	230	168	100	0	12	8	3	2	0	12	15	2
13	400	230	168	50	50	12	8	3	2	0	12	15	2
14	400	230	168	70	30	12	8	3	2	0	12	15	2
15	400	230	168	30	70	12	8	3	2	0	12	15	2
16	1200	690	480	0	100	12	8	3	2	0	12	15	2
17	1200	690	480	100	0	12	8	3	2	0	12	15	2
18	1200	690	480	50	50	12	8	3	2	0	12	15	2
19	1200	690	480	70	30	12	8	3	2	0	12	15	2
20	1200	690	480	30	70	12	8	3	2	0	12	15	2
21	2000	1150	800	50	50	12	8	3	0	2	12	15	2
22	2000	1150	800	50	50	12	8	3	2	0	12	15	2

Table 7 – Scenarios Analyzed for the Operation of the Port of Guaymas

The second factor considered in the development of the scenarios was the total weekly demand of import containers. The first level of demand for import containers (400 TEU), presented in Table 7, was selected according to the baseline demand of the containers required to attract a shipping line, as it is explained in Section 4 of the full report. The second level of demand (1,200 TEU) was selected to represent the level of operation of a consolidated container terminal, such as the Port of Ensenada that currently handles around the 1,200 TEU. For the third level of demand (2,000 TEU) we focused on determining the maximum capacity at the port after a long period of time, but without requiring a major change or expansion in its infrastructure. TEU represent twenty-feet equivalent unit, however in the case of containers bound for the US market is more common to have 40 feet containers, so the 400 TEU are converted into 230 containers (70% of 40' and 30% of 20'). The level of demand selected, indicates the amount of containers being imported, but if we add the export containers, which we assumed are between 75% and 100% of the import cargo, then the port will process around 400-460, 1200-1380 and 2010-2300 containers respectively, for each of the demand levels. The third factor is the transportation mode preferred by the costumers of the port. Since these preferences are not certain at this time, we explore six different combination of transportation mode shares all by train, 50% train, and 50% truck, 70-30, 30-70 and all by truck, as presented in Table 7.

4. Results

The simulations ran for three years worth of operations at the Port, with 10 replications for each scenario, with the purpose of having enough information to represent results such as confidence intervals among the different scenarios.

The results of these scenarios are presented in Table 8. The first column of this table gives the scenario number. The seventh column gives the ship turnaround time in hours. This is the time it takes for a ship to be serviced by the Port of Guaymas from the time it arrives to the outside stopping buoy to the time it leaves the port. The eighth column gives the time in hours the ship was docked in the port. Columns nine and ten represent the time a container takes to leave the port in hours from the time it arrives to the port to the times it leaves the port by either train or truck. The next two columns –11 and 12: show the number of loaded containers leaving the port by train or truck in a simulated period of two years. Column thirteen gives the average number of containers in the container yard during the simulated period. The fourteenth column gives the average utilization for berth three. In this case it is important to highlight that berth four was never used in the simulation. The last column gives the maximum utilization (in containers) of the container yard. For this it was assumed that the port worked a schedule of 24 hours/7 days a week and that it was assumed that the ships were uniformly spaced during the week and each ship carried an average of 400 TEU.

		Containers/Week		Ship Method										
Cases	TEU	Full	Empty	Truck	Train	T/A Vessel	Time in Dock	Time Rail	Time Truck	# Cont Rail	# Cont Truck	# Cont Yard	Dock Util	Max Yard
1	400	230	168	0	1	27.12	25.62	32.32	--	24112.7	--	123.18	0.15	384
2	400	230	168	1	0	27.05	25.55	--	11.09	--	24109	92.52	0.15	311
3	400	230	168	0.5	0.5	27.1	25.6	30.27	11.14	11878.4	12233	106.39	0.15	314
4	400	230	168	0.3	0.7	27.05	25.56	29.03	12.04	16656.8	7429	110.91	0.15	328
5	400	230	168	0.7	0.3	27.05	25.55	37.03	11.09	7112	16987	103.42	0.15	314
6	1200	690	480	0	1	26.02	25.25	33.32	--	71881.6	--	192.83	0.45	391
7	1200	690	480	1	0	26.01	25.23	--	11.09	--	718812	99.57	0.45	315
8	1200	690	480	0.5	0.5	26.03	25.25	26.71	11.18	35579.2	36353	132.49	0.45	319
9	1200	690	480	0.3	0.7	26.02	25.25	28.43	12.58	49844	22073	152.22	0.45	337
10	1200	690	480	0.7	0.3	26.03	25.25	28.89	11.11	21327.2	50619	121.77	0.45	309
11	400	230	168	0	1	12.17	10.82	32.3	--	24100.8	--	125.72	0.06	466
12	400	230	168	1	0	12.16	10.8	--	7.12	--	24115	90.1	0.06	436
13	400	230	168	0.5	0.5	12.2	10.83	26.56	7.07	11916.8	12213	104.33	0.06	445
14	400	230	168	0.7	0.3	12.2	10.84	32.63	7.16	7150.4	16981	101.72	0.06	450
15	400	230	168	0.3	0.7	12.2	10.84	29.48	6.97	16734.4	7403	112.59	0.06	454
16	1200	690	480	0	1	11.48	10.75	31.44	--	71856.8	--	201.16	0.19	474
17	1200	690	480	1	0	11.46	10.73	--	7.11	--	71855	98.77	0.19	446
18	1200	690	480	0.5	0.5	11.48	10.74	23.94	7.07	35636.8	36296	134.35	0.19	449
19	1200	690	480	0.7	0.3	11.48	10.75	25.29	7.17	21276.8	50617	122.12	0.19	445
20	1200	690	480	0.3	0.7	11.48	10.75	27.04	6.97	49760	22187	157.2	0.19	461
21	2000	1150	800	0.5	0.5	24.3	23.7	25.1	11.23	70980	72624	160.83	0.83	311
22	2000	1150	800	0.5	0.5	10.71	10.14	23.01	7.09	71068	72628	168.89	0.35	436

Table 8 – Results for the Scenarios Analyzed for the Operation of the Port

Some of the results that can be obtained from the simulation include:

- There is significant difference between the turnaround times for the scenarios with and without quay cranes. This difference is of about 14 hours. The average time without quay cranes is of about 26.34 hours and 11.73 for the scenarios with quay cranes (see Figure 7 and Figure 8). This is consistent with the time around time reported by the Port of Manzanillo for similar scenarios.

- The capacity of the container yard did not represent a constraint under the simulated conditions. However, the assumption made was that the containers would leave the container yard as soon as transportation was available. This is consistent with a transshipment (or export) operation, but overly optimistic for a domestic operation.

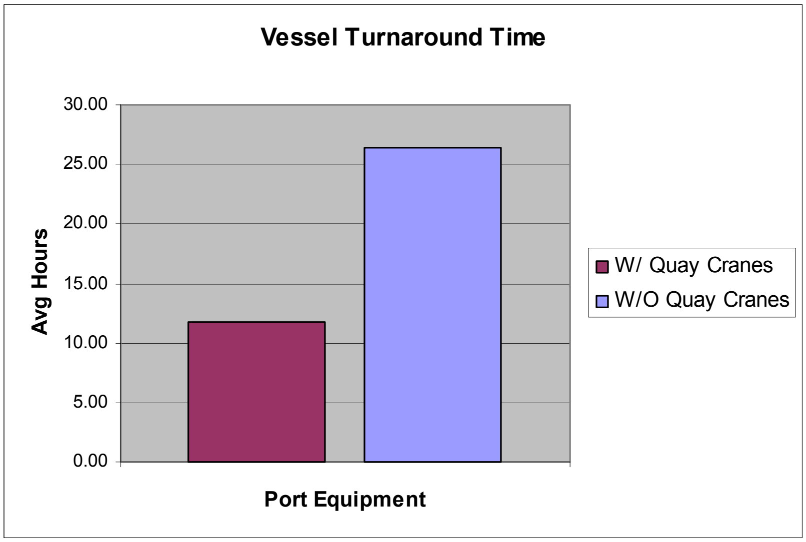

Figure 7 - Vessel Turnaround Time Comparison between Levels of Equipment

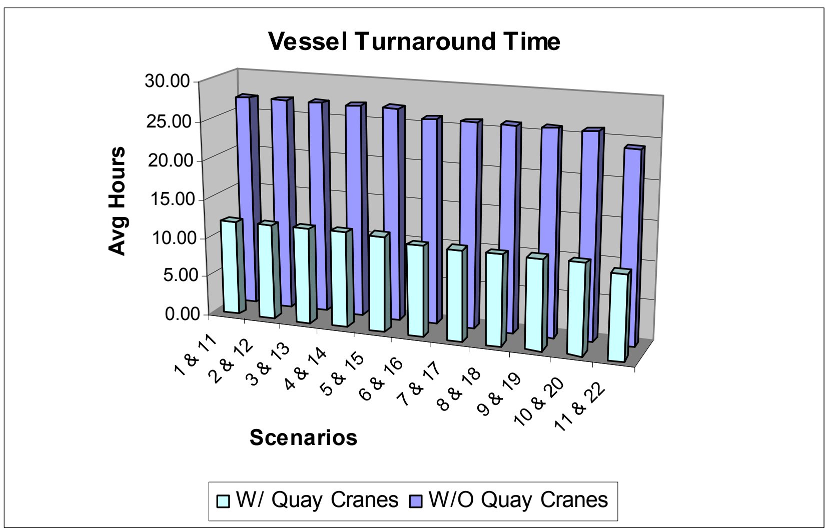

Figure 8 - Vessel Turnaround Time Comparison among Scenarios

- Under the simulated conditions the docking facility does not seem to be a major constraint for the capacity of the port. However, it was observed that the utilization for one of berths at the maximum level of demand approached 85% when the cranes of the ship were used to unload/load containers. This is in contrast with the 35% reported when quay cranes are used. Something that needs to be mentioned is that the simulation used only one of the berths available. On the surface this would seem to imply that the capacity reported (175,000 TEU) would be obtained with only one berthing position. However, we cannot make this claim because the simulation was based on the assumption that six ships per week would visit the port in a time uniform basis. This is hardly the case in real-life situation. Thus, the capacity number reported should be read as being based on the availability of two berthing position. A higher resolution simulation could be used to refine the capacity estimate.

- Although the simulation was not run to the limit of the capacity of the port, we can draw the inference that the crane (or the lack thereof) factor was the main determinant of the capacity of the operation of the container terminal.

- The maximum capacity analyzed was based on similar operations. We believe that this capacity (around 175,000 TEU) represents a lower limit of the capacity of the port rather than a hard upper limit. However, with the information available at the time of the study it was the number with which we felt comfortable. A more precise study could provide a revised capacity of the Port of Guaymas.

- From the perspective of the time needed to for a container to leave the port, from the results of the simulation, we can see that the truck option is more efficient (see Figure 9 and Figure 10). However, this alternative could be significantly more expensive than the rail alternative.

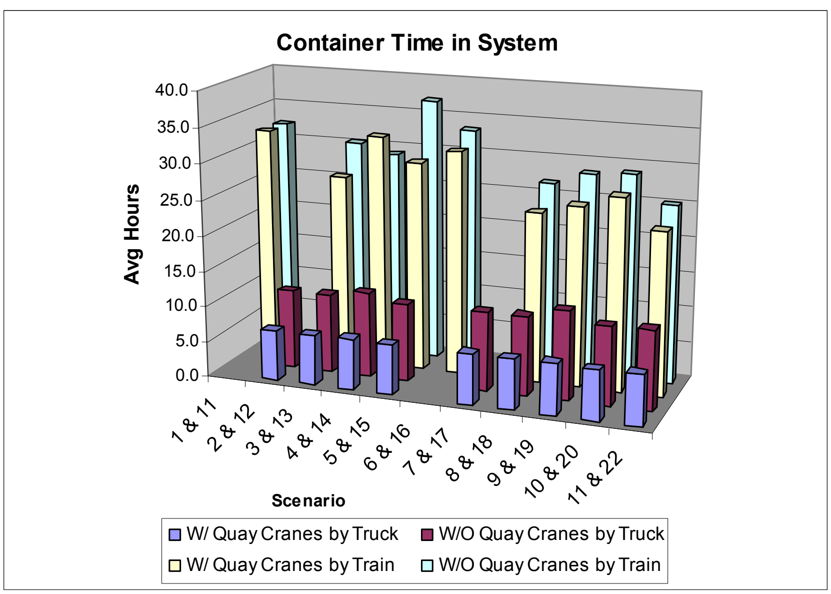

Figure 9 - Average Time Obtained for All the Scenarios

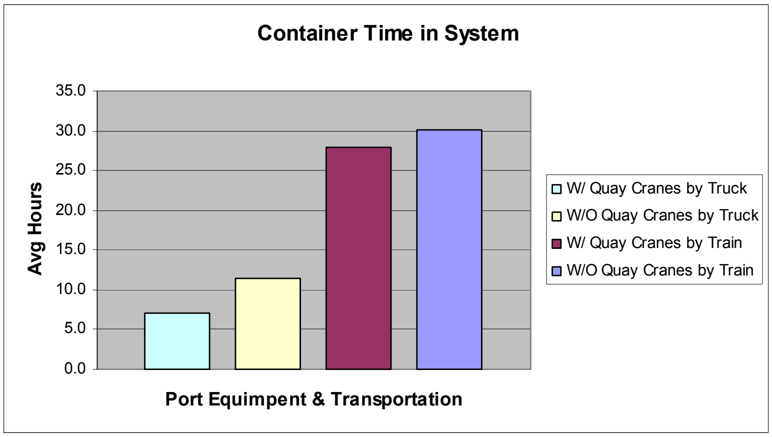

Figure 10 - Average Time by the Containers at the Port

4.1. Statistical Evaluation

The 95% Confidence Interval (CI) of three different metrics of the simulation of the Port of Guaymas were estimated:

- Vessel turnaround time
- Time in system of containers being moved by truck
- Time in system of containers being moved by railroad

To calculate these CI's the following formula was used:

$$CI = \bar{x} \pm t_{\alpha/2,(n-1)} S\sqrt{n} \ , \qquad (1)$$

where CI represents the 95% confidence interval for each set of data with mean $\bar{x}$.

Vessel Turnaround Time

For the vessel turnaround time, the data obtained is presented next. As we can see there is an obvious difference between the scenarios ran under the assumption of not having quay cranes available (1 – 10 & 21) and the ones that do (11 -20 & 22). While the turnaround time mean for the first case vary between 1,400 minutes and over 1,600 minutes; the mean time for the second case varies in the 600's and 700's minutes (see Table 1).

Vessel Turnaround Time							
Scenario	Mean	Low 95%	High 95%	Scenario	Mean	Low 95%	High 95%
S1	1,611.52	1,607.46	1,615.57	S11	723.37	722.05	724.70
S2	1,607.54	1,604.77	1,610.31	S12	722.58	721.50	723.66
S3	1,610.44	1,607.13	1,613.75	S13	724.23	722.97	725.48
S4	1,607.71	1,604.69	1,610.73	S14	724.83	722.56	727.09
S5	1,607.64	1,603.13	1,612.14	S15	724.82	723.11	726.53
S6	1,556.47	1,555.03	1,557.91	S16	686.81	685.97	687.65
S7	1,555.74	1,553.46	1,558.02	S17	685.37	684.46	686.28
S8	1,556.86	1,554.88	1,558.83	S18	686.35	685.40	687.29
S9	1,556.37	1,554.15	1,558.60	S19	686.46	686.02	686.91
S10	1,556.60	1,554.82	1,558.38	S20	686.68	686.12	687.23
S21	1,453.36	1,452.11	1,454.61	S22	641.54	641.12	641.95

Table 9 - Reported Turnaround Time (Hours)

To have a better understanding of the difference the CI's were plotted and the following chart show's the results (see Figure 11). Since the intervals are so marginal between the two types of scenarios described before, we can conclude that there is a statistical difference in the turnaround times without having to perform any other tests. Based on this information it's confirmed that the difference in turnaround times for scenarios having quay cranes and not, it's significantly large and for that considered a potential improvement in the port.

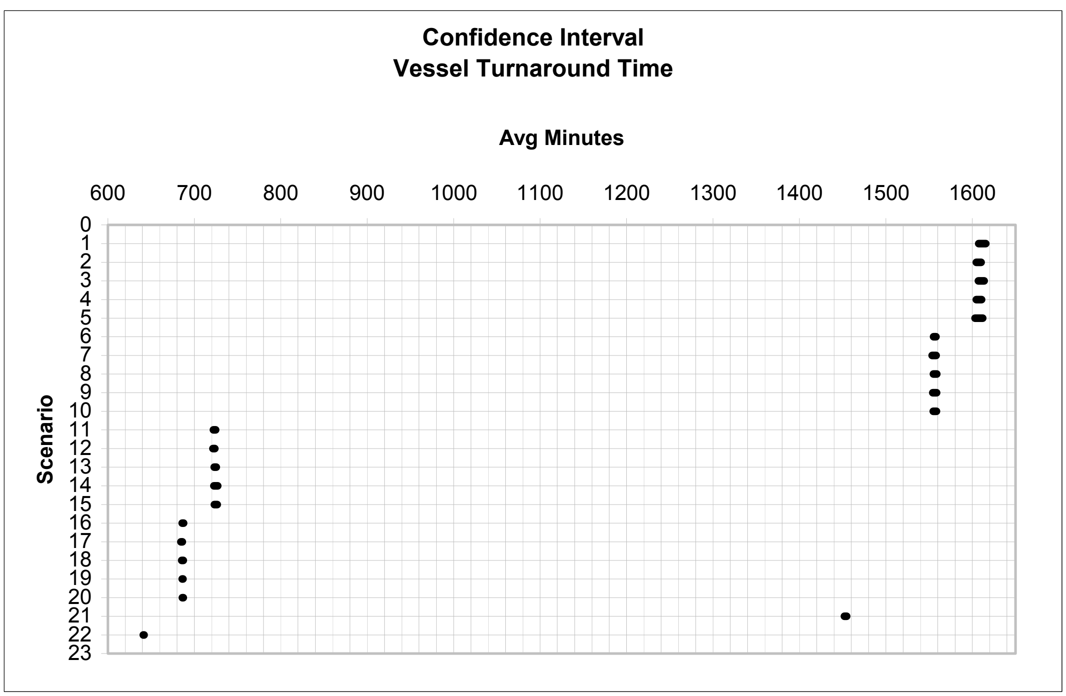

Figure 11 - Vessel Turnaround Time for All Scenarios

Looking by separate into scenarios with and without quay cranes, we found that scenarios 1, 2, 3, 4 & 5 have no statistical difference between them, but do against scenarios 6, 7, 8, 9 & 10 (see Figure 12). At the same time, scenarios 11, 12, 13, 14 & 15 have no difference between them but do against scenarios 16, 17, 18, 19 & 20 (see Figure 13).

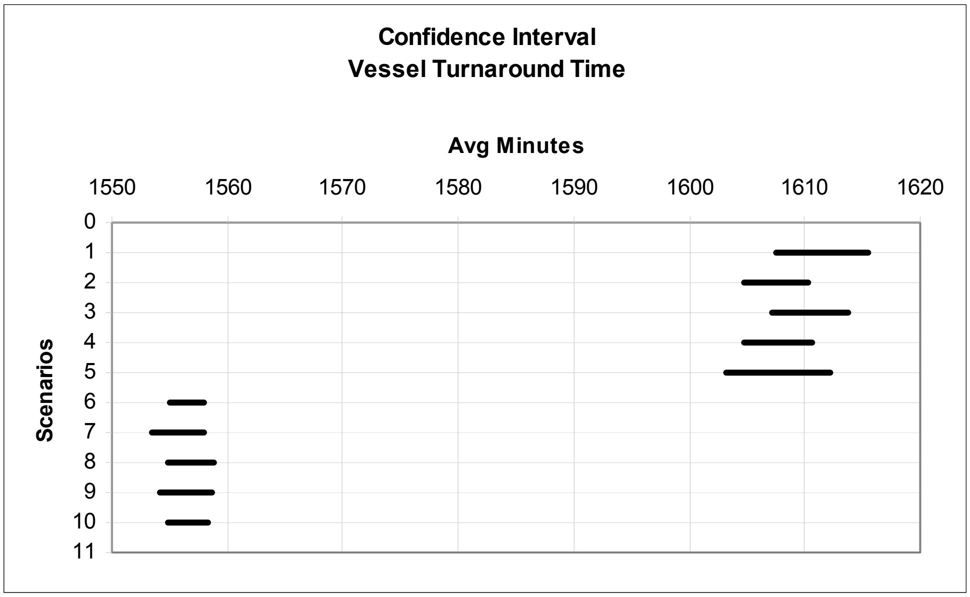

Figure 12 - Vessel Turnaround Time (with ship's cranes)

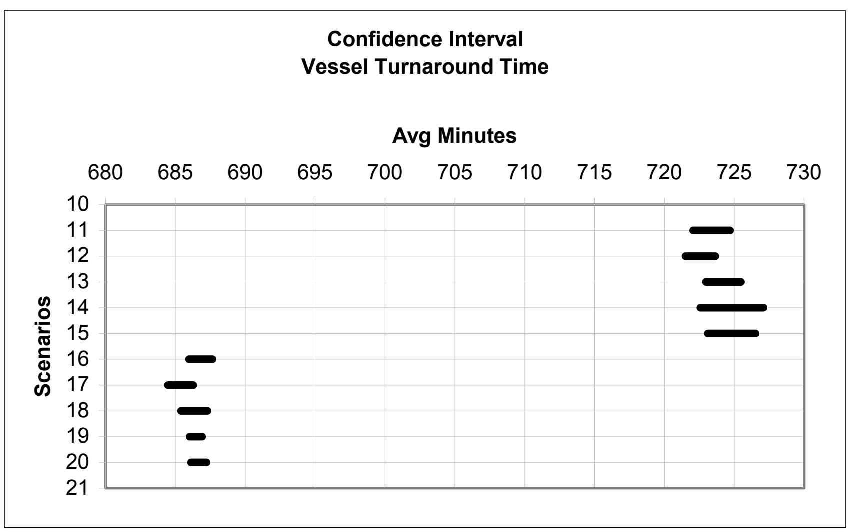

Figure 13 - Vessel Turnaround Time (with quay cranes)

Time in System of Containers being moved by Truck

The time in system of containers that arrive to the port and will be moved out of it by truck was analyzed too. Table 10 presents the data obtained from the simulations once the containers leave the terminal in average hours with low and high intervals.

Containers by Truck: Time in System							
Scenario	Mean	Low 95%	High 95%	Scenario	Mean	Low 95%	High 95%
S2	665.61	664.65	666.57	S12	427.22	426.77	427.67
S3	668.47	667.09	669.84	S13	424.02	423.43	424.60
S4	722.64	720.34	724.95	S14	429.76	429.23	430.30
S5	665.55	664.40	666.70	S15	418.47	417.72	419.23
S7	665.57	665.01	666.12	S17	426.78	426.52	427.04
S8	670.77	669.98	671.60	S18	424.36	424.02	424.70
S9	754.53	752.83	756.23	S19	429.91	429.60	430.22
S10	666.51	665.85	667.18	S20	418.38	417.94	418.83
S21	673.90	673.31	674.49	S22	425.67	425.43	425.92

Note: Scenarios 1, 6, 11 & 16 are not moved by Truck

Table 10 - Time at the Port in Hours

In this case it's also obvious that the time containers are in the port depends directly to the use of quay cranes. In the first scenarios (without quay cranes) the time a container spends in the port before being moved averages over 650 minutes, while in the last scenarios it's less than 450 minutes in average, which can be observed in graphically on Figure 14.

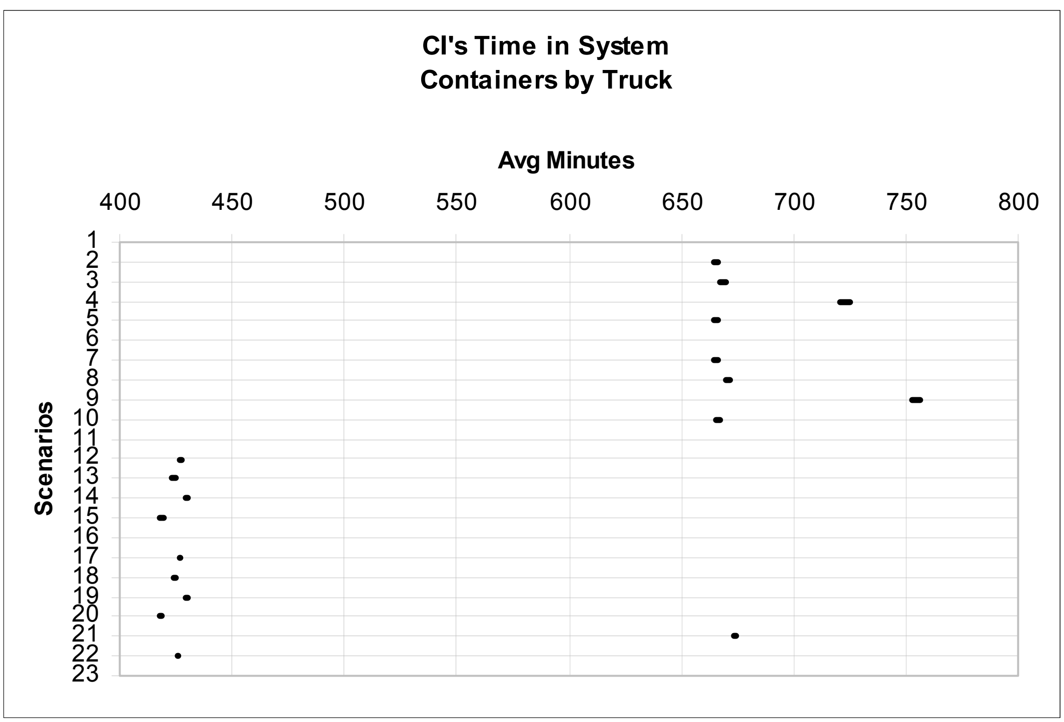

Figure 14 - Confidence Interval of Time at Terminal (all scenarios)

Based on this information once again it's confirmed that the difference in the time a container that will be moved by truck stays at the port it's significantly different when it's assumed that quay cranes are available or not. When looking at the scenarios that assumed not to have quay cranes we found that cases 2, 3, 5, 7 & 10 are statistically similar, but cases 4 & 9 differ from these and between each other (see Figure 15).

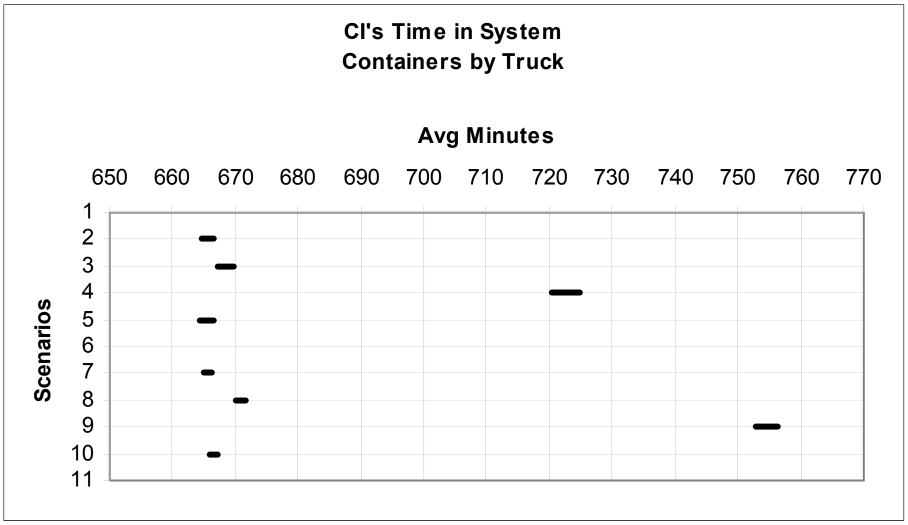

Figure 15 - Confidence Interval of Time at Terminal (scenarios with ship cranes)

On the other hand, while assuming that quay cranes were available, scenarios 15 & 20, 13 & 18, 12 & 17, and 14 & 19 are statistically similar pair wise but different from the others (see Figure 16).

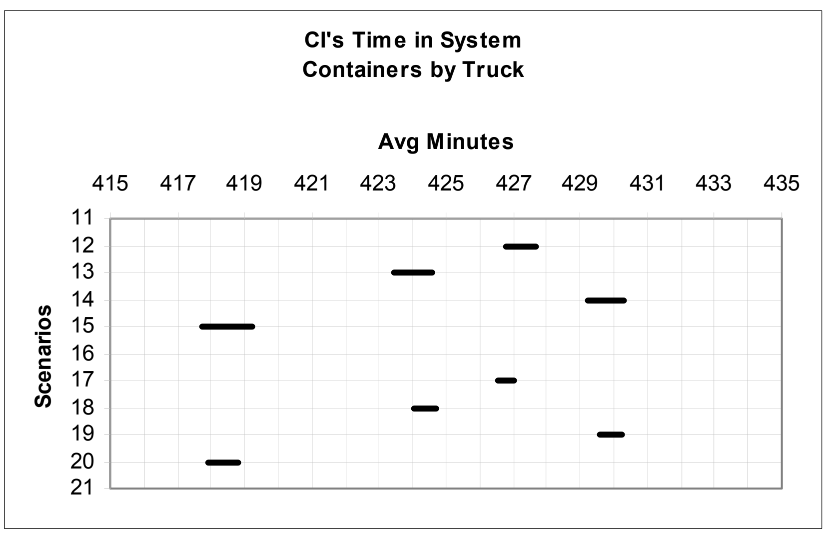

Figure 16 - Time Spent at the Terminal (containers by truck)

If more detail was to be required more tests should be performed to have a more accurate estimate of each scenario. For the purpose of this study there is enough information to conclude what has been mentioned before about the advantages in using quay cranes.

Time in System of Containers being moved by Railroad

The last metric for which CI's were calculated is the time in system that a container moved by railroad stays in the port. Using the same formula the following data is obtained (Table 11):

Containers by Railroad Time in System							
Scenario	Mean	FCCI low	FCCI high	Scenario	Mean	FCCI low	FCCI high
S1	1,939.40	1,932.30	1,946.40	S11	1,938.10	1,931.10	1,945.20
S3	1,816.30	1,802.50	1,830.00	S13	1,593.90	1,580.20	1,607.50
S4	1,741.90	1,731.90	1,752.00	S14	1,957.60	1,935.30	1,979.90
S5	2,221.70	2,199.60	2,243.70	S15	1,768.50	1,758.50	1,778.50
S6	1,999.40	1,997.30	2,001.60	S16	1,886.60	1,884.40	1,888.80
S8	1,602.60	1,599.80	1,605.40	S18	1,436.70	1,433.80	1,439.60
S9	1,705.90	1,703.50	1,708.30	S19	1,517.50	1,513.00	1,521.90
S10	1,733.20	1,728.90	1,737.40	S20	1,622.20	1,619.70	1,624.70
S21	1,506.10	1,504.70	1,507.40	S22	1,380.40	1,379.00	1,381.80

Note: Scenarios 2, 7, 12 & 17 don't dispatch by Rail

Table 11 - Time Spent in the Terminal for Container Moving by Railroad

In this case the big difference observed in previews charts is not replicated (see Figure 17). Still, there is a clear tendency of reduced average time in system of containers in scenarios that assumed the usage of quay cranes. This can be explained by the fact of having a rail schedule and not being able to ship every container at the moment is ready.

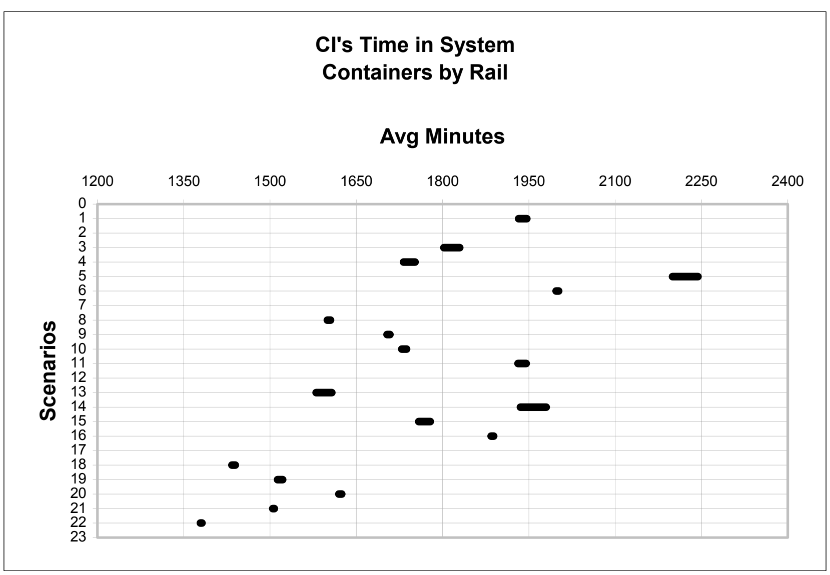

Figure 17 - Time Containers Spent at Terminal (all scenarios)

5. Validation

In order to verify and validate the simulation model we follow two approaches: verifying with experts and comparing the results of the simulation with operations of similar characteristics. After the first version of the simulation for the Port of Guaymas was finished we invited the operations personnel to review the simulation and the assumptions included in the model. From this review the personnel from the port agreed on the general validity of the assumptions and we made some minor adjustments to the model.

In order to further validate the simulation model we compared the performance measures given by the simulation with the performance of an operating port. The data we used are the first 11 months from the year 2005 for the container operations in the Port of Manzanillo, Mexico. We made the comparison for the operations based on the turnaround times of the container ships for the cases when the cranes of the ships were used to unload and load containers and also for the cases for which quay cranes had been used. For ship's cranes we first determined the relationship between the numbers of containers with total turnaround time. The relationship can be assumed as linear as demonstrated by Figure 18, which plots the number of hours at the port against the total number of containers for import and export.

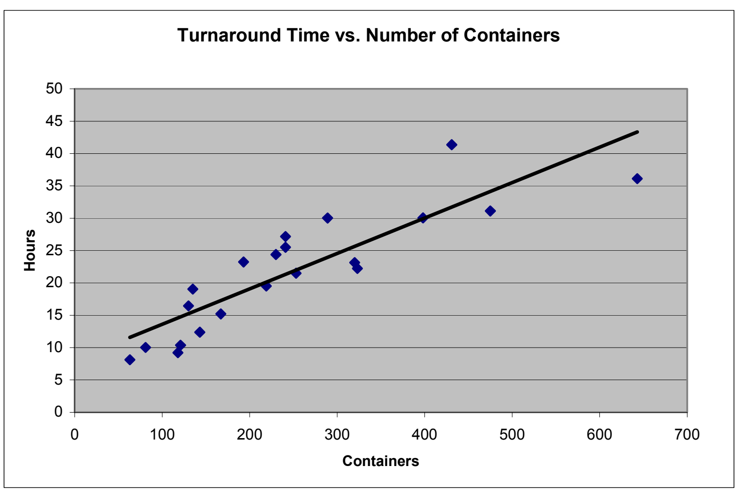

Figure 18 - Turnaround Time Relationship

Using this relationship to estimate the average time each vessel spends at the port, given the total amount of container to load and unload, we estimated the relationship provided by a regression analysis presented in Table 12.

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	8.12921382	2.006746613	4.0509	0.00068	3.9290449	12.3293827
X Variable 1	0.05475192	0.007023527	7.7955	2.5E-07	0.0400515	0.06945233

Table 12 - Regression Analysis for Ship Crane

The second validation was the turnaround time of the vessels using quay cranes, using the same information from the Port of Manzanillo. First determining the relationship between the total containers loaded and unloaded with the overall time spent at the port (Figure 19).

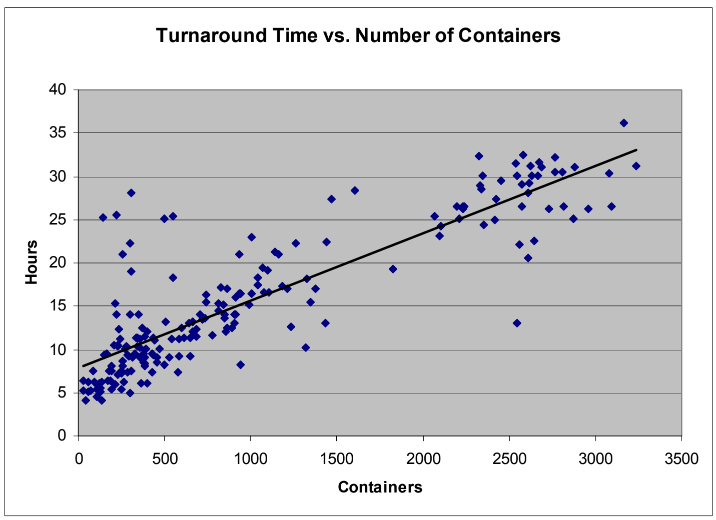

Figure 19 - Turnaround Time Relationship

Using a linear relationship we estimate the expected turnaround time, which is dependent on the total number of containers to process on the vessel. The time is estimated through a regression analysis, generating the results presented in Table 13.

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	7.87852989	0.444608507	17.7202	2.42E-42	7.00161446	8.75544531
X Variable 1	0.00778107	0.000325406	23.9119	1.31E-59	0.00713926	0.00842287

Table 13 - Regression Analysis for Quay Crane

The results obtained from both analyses render the following estimation for the turn around time of the vessels:

Turnaround (Hours) = 8.129 + 0.547(Containers) Ship cranes

Turnaround (Hours) = 7.878 + 0.007(Containers Quay cranes

These results when compared to the average time calculated by our simulation model supported the validity of the simulation model, since the results similar to the ones being reported by the Port of Guaymas.

Although we believe that the current simulation model reflects the general operation of a container terminal, we also believe that this simulation model can be significantly improved by having access to higher-level of data detail. For instance, some of the parameters are based on historical averages rather than precise distribution. The availability of this data would render a more precise, higher resolution simulation model.

6. Conclusions

The validation of the assumptions in our model, gives us confidence in the validity of the results from this simulation. The statistical evaluation of the results allows us to have confidence on the significance of the results, that its, that the differences perceived are not generated by the randomness in the system, but that the factors tested really make an impact in the performance measures of the system, such as turnaround time for the vessels and waiting time of containers at the Port. With these evaluations we can be certain that the recommendations we provide based on the simulation are based on an adequate abstraction of the model.

Finally we recommend that this model should not be used to determine other results, other than the rough capacity and performance estimation of the initial period of operation for the Port of Guaymas, according to the current state of its infrastructure and some future improvements that we specified on this report.